CALICE DHCAL Runs at FTBF

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Fermilab All Experimenters Meeting
December 19, 2011

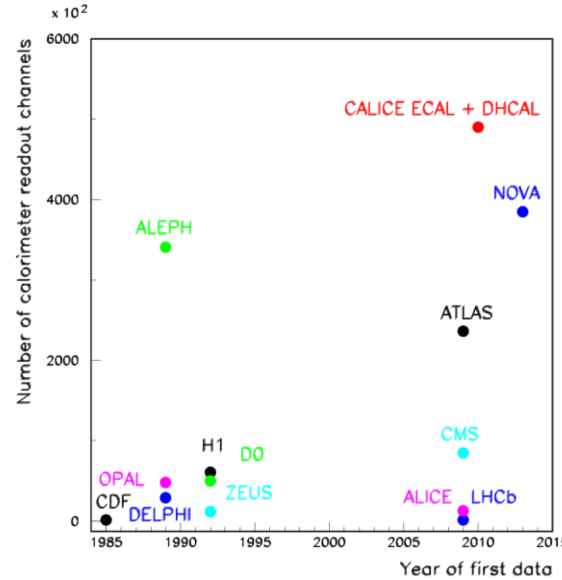
The DHCAL Project

RPC – based imaging calorimeter

DHCAL = First large scale calorimeter prototype with

Embedded front-end electronics
Digital (= 1 – bit) readout
Pad readout of RPCs (RPCs usually read out with strips)

DHCAL = World record channel count for calorimetry



Argonne National Laboratory
Boston University
Fermi National Accelerator Laboratory
IHEP Beijing
Illinois Institute of Technology
University of Iowa
McGill University
Northwestern University
University of Texas at Arlington

DCHAL Collaboration	Heads
Engineers/Technicians	22
Students/Postdocs	9
Physicists	10
Total	**41**

…and integral part of

CALICE
Calorimeter for ILC

1 m^3 – Digital Hadron Calorimeter Physics Prototype

Description

Readout of 1 x 1 cm^2 pads with one threshold (1-bit) → **Digital Calorimeter**
Layers inserted into the existing CALICE Analog (scintillator) HCAL and TCMT structures
38 layers in DHCAL and 14 in tail catcher (TCMT), each ~ 1 x 1 m^2
Each layer with 3 RPCs, each 32 x 96 cm^2
~480,000 readout channels

Purpose

Validate DHCAL concept
Gain experience running large RPC systems
Measure hadronic showers in great detail
Validate hadronic shower models (Geant4)

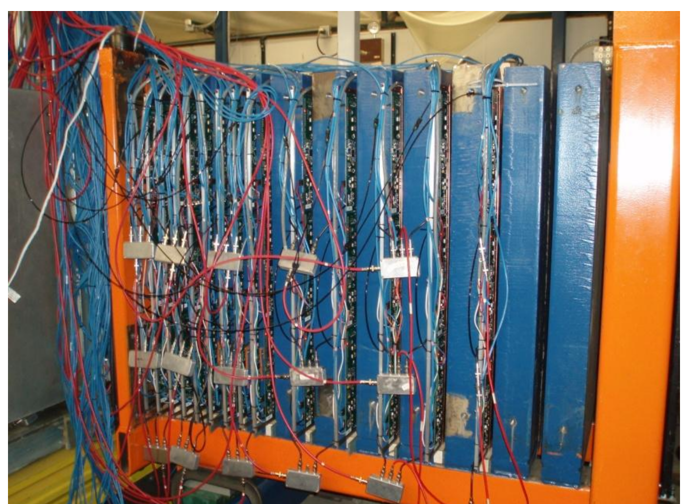
Status

Started construction in 2008
Completed in 2010
Several test beam campaigns at Fermilab

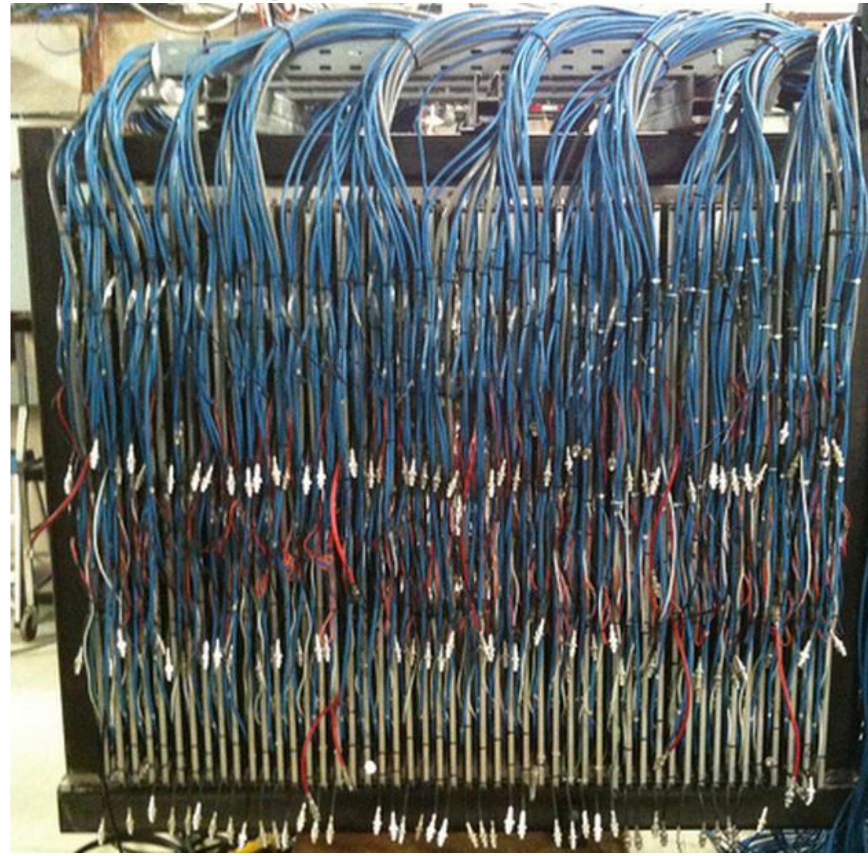
The DHCAL in the Test Beam

	Date	DHCAL layers	RPC_TCMT layers	SC_TCMT layers	Total RPC layers	Total layers	Readout channels
Run I	10/14/2010 – 11/3/2010	38	0	16	38	54	350,208+320
Run II	1/7/2011 – 1/10/2011	38	0	8	38	46	350,208+160
	1/11/2011 – 1/20/2011	38	4	8	42	50	387,072+160
	1/21/2011 – 2/4/2011	38	9	6	47	53	433,152+120
	2/5/2011 – 2/7/2011	38	13	0	51	51	470,016+0
Run III	4/6/2011 – 5/11/2011	38	14	0	52	52	479,232+0
Run IV	5/26/2011 – 6/28/2011	38	14	0	52	52	479,232+0
Run V	11/2/2011 – 12/6/2011	50	0	0	50	50	460800

~ 480K readout channels
~ 35M events



The Latest Test Beam Campaign



November 2, 2011 – December 6 2011

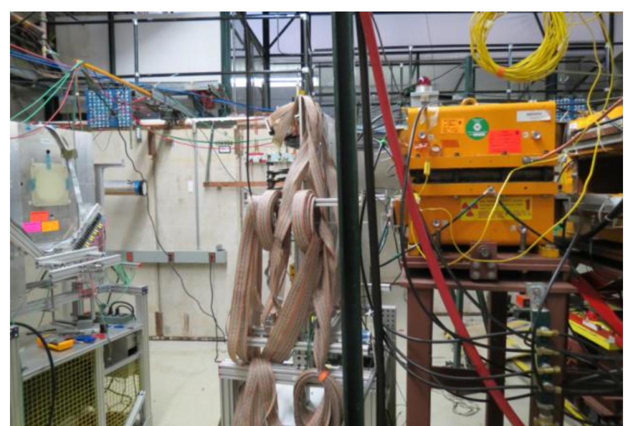
50 layers, no absorber

→ 13 X_0
→ 1.3 λ_I

460800 readout channels

Well prepared for the tertiary beam:
0.2 – 2 GeV/c

→ The tertiary beamline did not work
→ Took a lot of positron data



General DHCAL Analysis Strategy

Noise measurement (CAN-031)

- Determine noise rate (correlated and not-correlated)
- Identify (and possibly mask) noisy channels
- Provide random trigger events for overlay with MC events (if necessary)

Measurements with muons (CAN-030)

- Geometrically align layers in x and y
- Determine efficiency and multiplicity in ‘clean’ areas
- Simulate response with GEANT4 + RPCSIM (requires tuning 3-6 parameters)
- Determine efficiency and multiplicity over the whole 1 x 1 m^2
- Compare to simulation of tuned MC
- Perform additional measurements, such as scan over pads, etc…

Measurement with positrons (CAN-032)

- Determine response
- Compare to MC and tune 4^{th} (d_{cut}) parameter of RPCSIM
- Perform additional studies, e.g. software compensation…

Measurement with pions (CAN-032)

- Determine response
- Compare to MC (no more tuning) with different hadronic shower models
- Perform additional studies, e.g. software compensation, leakage correction…

CAN: Calice Analysis Note → preliminary results

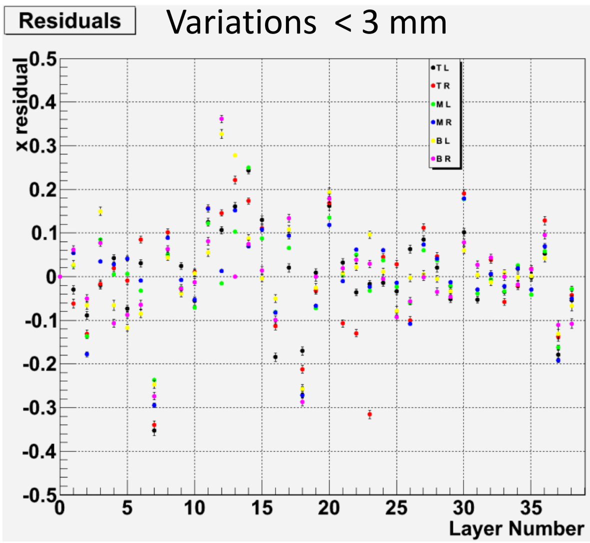
Alignment

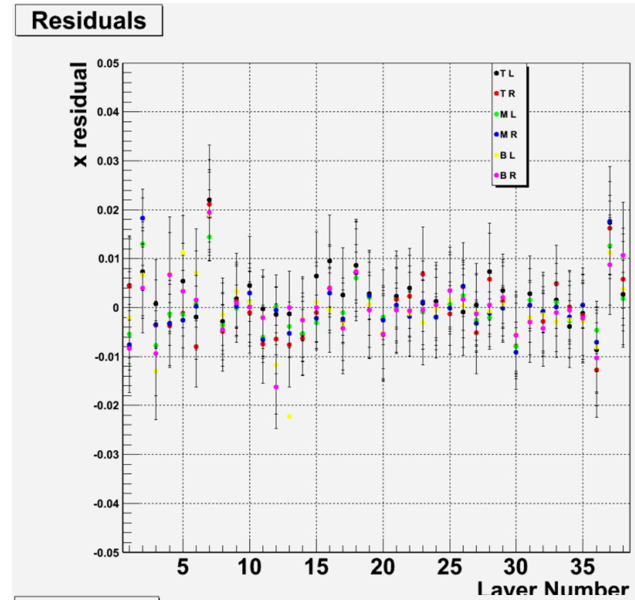
For each readout board i plot residual in x/y

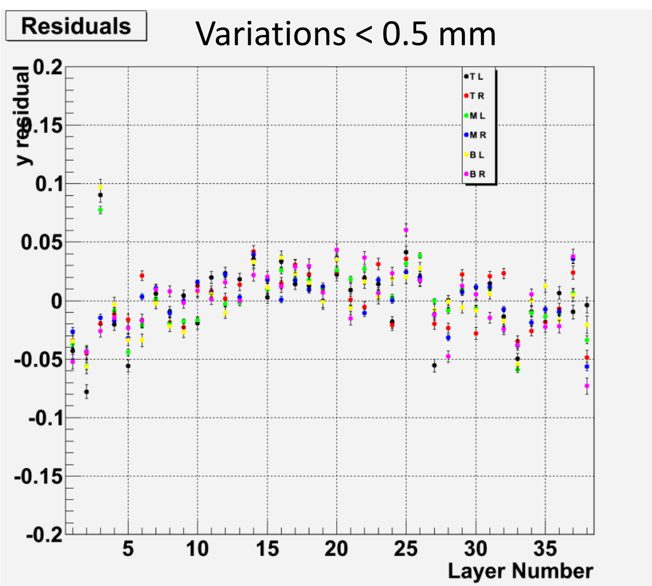
$R^i_x = x^i_{cluster} - x^i_{track}$

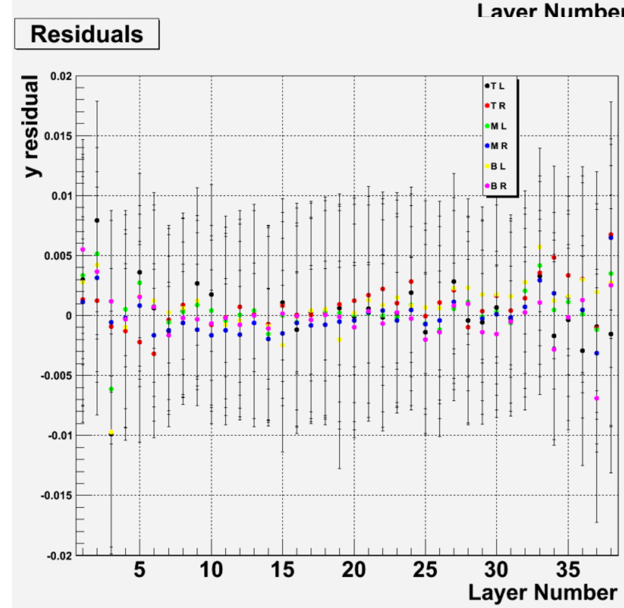
$R^i_y = y^i_{cluster} - y^i_{track}$

Dimensions in [cm]



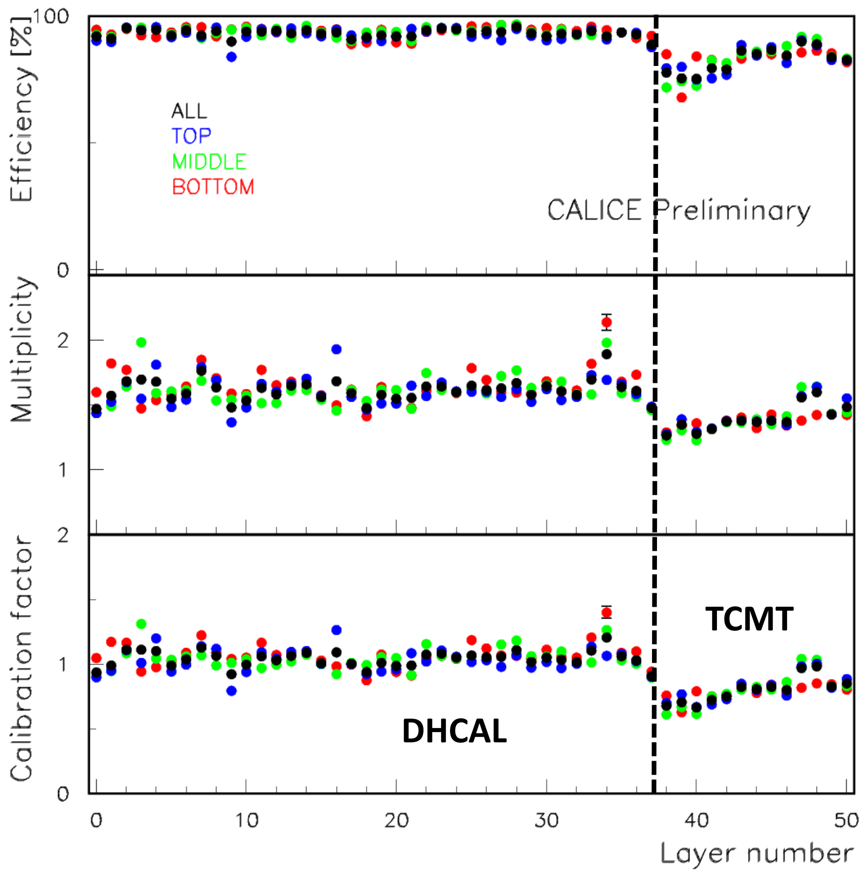


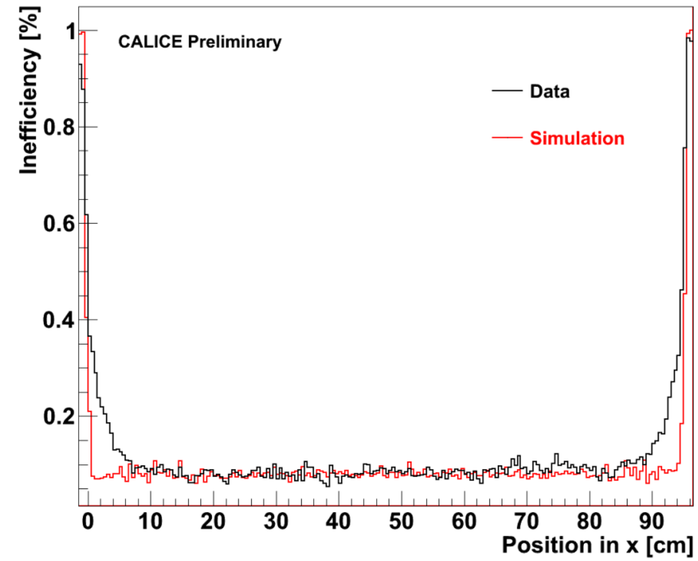


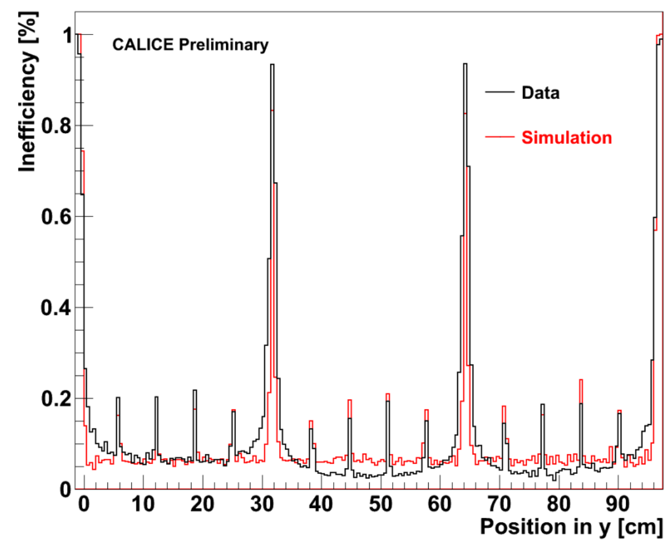


Efficiencies, multiplicities

Tail catcher is cooler
→ lower efficiency, multiplicity

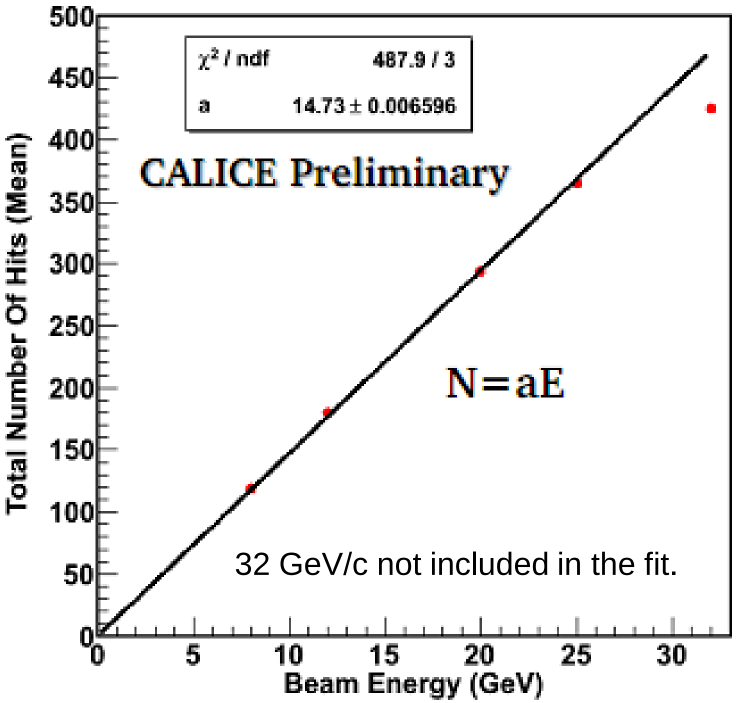


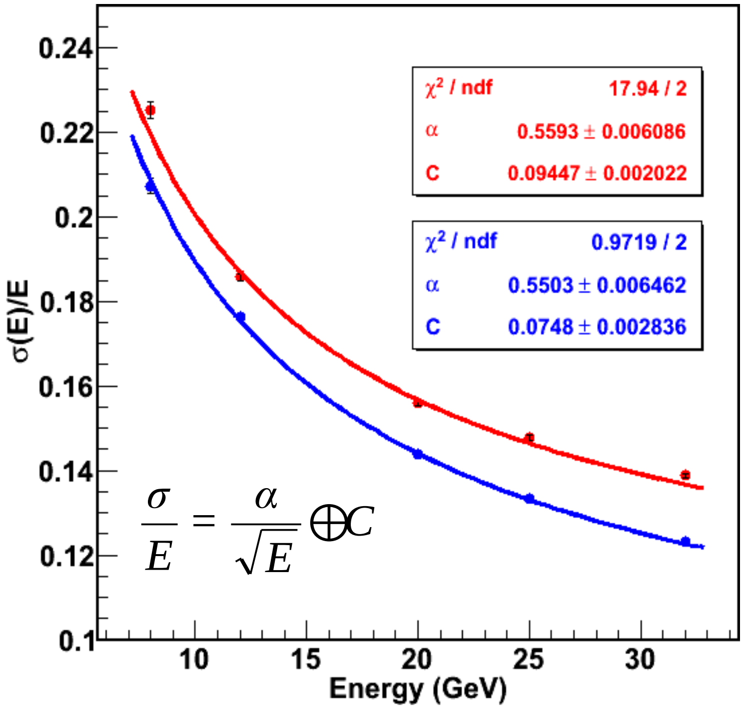




Calibration factors = mean of multiplicity distribution/(average over detector) = $\varepsilon \cdot \mu / \varepsilon_0 \cdot \mu_0$

DHCAL Response to Hadrons **response not calibrated**

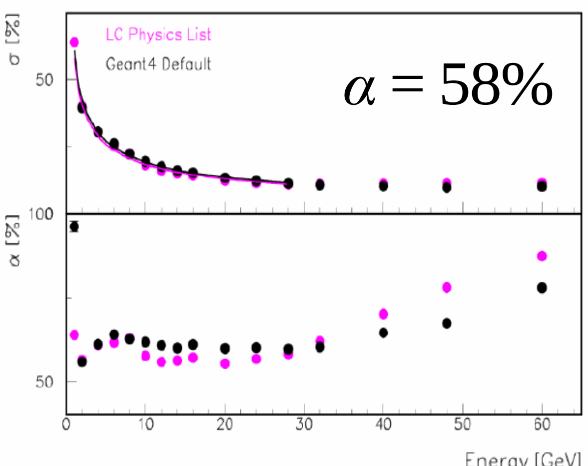




Standard pion selection

+ No hits in last two layers (longitudinal containment)

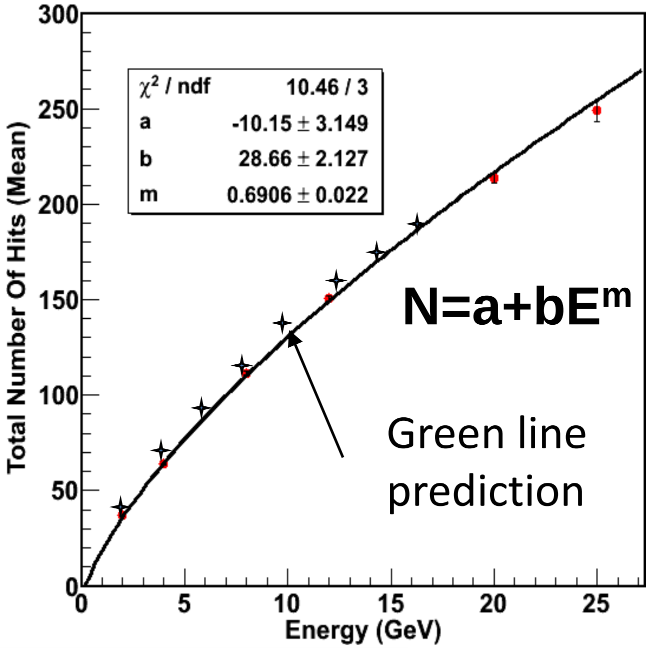
Topological particle identification – details can be found in Calice Analysis Note CAN-032

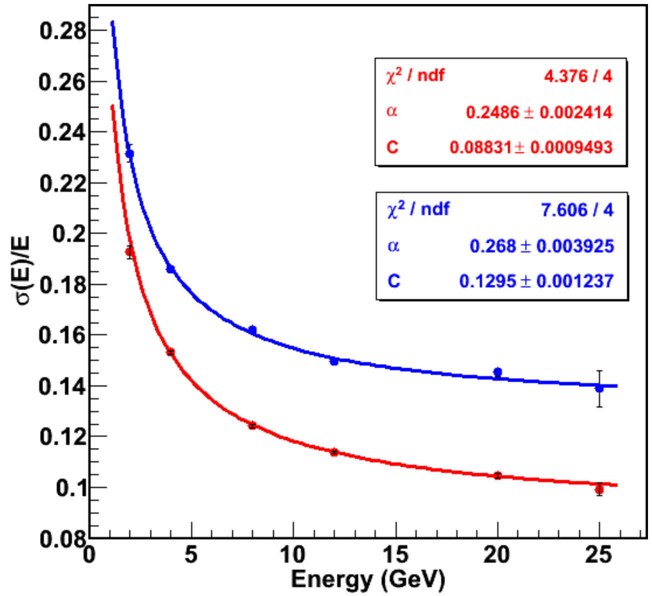


B. Bilki et.al. JINST4 P10008, 2009.

MC predictions for a large-size DHCAL based on the Vertical Slice Test.

DHCAL Response to Positrons **response not calibrated**



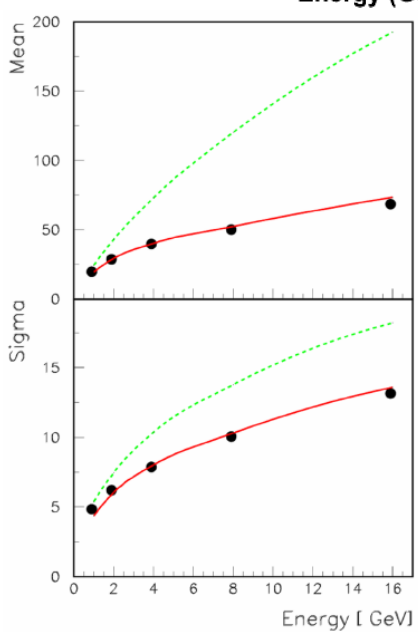


$$\frac{\sigma}{E} = \frac{\alpha}{\sqrt{E}} \oplus C$$

Uncorrected for non-linearity
Corrected for non-linearity

Correction for non-linearity

Needed to establish resolution
Correction on an event-by-event basis



B. Bilki et.al. JINST4 P04006, 2009.

Data (points) and MC (red line) for the Vertical Slice Test and the MC predictions for a large-size DHCAL (green, dashed line).

Conclusion

Hadron showers were observed with unprecedented spatial resolution.

DHCAL-specific algorithms are being generated.

Calorimetric properties are within expectations with a first-look analysis.

Significant progress in 2012 is expected. Next steps in the analysis:

- Calibrate the DHCAL
- Fine-tune the simulations
- Final calorimetric measurements
- Physics measurements (shower shapes, software compensation, detailed modeling of hadronic interaction, etc.)

The DHCAL concept is being validated.

FTBF Beam Test program finished.

Moving to CERN:

- 2 weeks in PS beamline in March 2012 with tungsten absorbers.
- 2 x 3 weeks in SPS beamline in Spring/Fall 2012 with tungsten absorbers.